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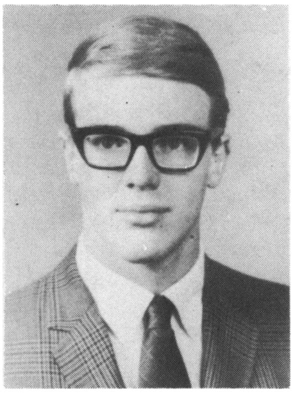

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VALIDITY OF THE ÅSTRAND-RYHMING NOMOGRAM FOR PREDICTING MAXIMAL OXYGEN INTAKE

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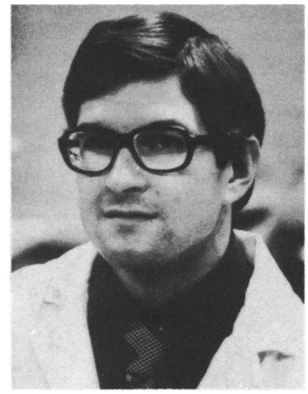

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ABSTRACT

The purpose of this study was to evaluate the validity of the predicted $\dot{V}O_2$ max from the Åstrand-Ryhming nomogram, using the cycle ergometer as the sole exercise mode and following the recommended submaximal test protocol. In addition, two sets of age correction factors were compared for accuracy. Using the Åstrand age correction factors, the *SEE* of the predicted $\dot{V}O_2$ max for the 40 male subjects was .42 $L.min^{-1}$ or 5.7 $ml.kg^{-1}.min^{-1}$, (r = .76 and .83, respectively); there was no significant difference between the measured and the predicted means. Although virtually identical *SEE* and r were found when applying the von Dobeln age correction factors, a significantly lower predicted mean was found ($p < .05$), which indicated a consistent tendency to underestimate the actual $\dot{V}O_2$ max. These results suggest that the Åstrand age correction factors should be used in conjunction with the Åstrand-Ryhming nomogram, especially when classifying subjects into various fitness classifications.

The original Åstrand-Ryhming nomogram was computed from the data for 58 subjects who performed submaximal tests on a cycle ergometer and maximal tests on either a cycle ergometer or a treadmill (P.-O. Åstrand and Ryhming, 1954). However, the 144 subjects tested for the modification of the nomogram used only the cycle ergometer for their submaximal and maximal tests. The data from both sets of subjects were combined to form the modified nomogram (I. Åstrand, 1960). The current version of the Åstrand-Ryhming nomogram, therefore, was primarily computed using the response to a submaximal cycle ergometer test to predict the $\dot{V}O_2$ max elicited during a maximal ergometer test. At the time of the modification of the nomogram, it was suggested that the cycle ergometer, the treadmill, or the step should be interchangeable for the submaximal test. In addition, an early study (P.-O. Åstrand, 1952) of maximal test procedures was cited as demonstrating that cycling and running elicited identical $\dot{V}O_2$ max measurements in young subjects. Subsequent work by many authors does not confirm this generalisation, thus it would appear that the most appropriate method of evaluating the validity of the nomogram would be to duplicate the test modes used for its computation and to use the heart rate response during a submaximal cycle ergometer test to predict the $\dot{V}O_2$ max elicited by a maximal bicycle ergometer test.

The purpose of this study was to evaluate the predicted $\dot{V}O_2$ max from the Åstrand-Ryhming nomogram, using the cycle ergometer as the sole exercise mode and following the recommended procedures for the submaximal test, and to compare the accuracy of the age correction factors associated with the modified nomogram to age correction factors later proposed by von Dobeln, Åstrand et al (1967).

METHODS

The test results of 40 men students between 18 and 33 years of age were used in this study. Fifty-one volunteers completed testing, but only 40 met the criterion used with the maximal test; their physical characteristics were height 179.5 ± 17.03 cm, weight 75.90 ± 11.86 kg and ages 23.8 ± 3.8 years.

All tests were performed on a Monark cycle ergometer with the seat height adjusted such that the subject's knee was slightly flexed when the ball of the foot rested on the pedal at the lowest point in a revolution. Heart rates were monitored and recorded using a Quinton ECG Monitoring System (model 621 B). The ambient temperature range was about 23.8°C.

Submaximal Test

Each subject was asked to describe his habitual physical activity. Based on this description, a subjective evaluation of his fitness level was made. Initial work loads of 150, 100 and 75 W at 50 pedal revs per min. were used for well-trained, moderately trained, and untrained subjects, respectively. If the heart rates for the fifth and sixth minutes did not differ by more than 5 bpm and if their mean value was between 130 and 170 bpm, the test was stopped. If the mean was less than 130 bpm, the work load was increased and the test continued. If the heart rates differed by more than 5 bpm, the test was continued until this criterion was met (P.-O. Åstrand, a).

The predicted $\dot{V}O_2$ max was read from the nomogram (I. Åstrand, 1960) or accompanying tables (P.-O. Åstrand, a) and multiplied by both the Åstrand and the von Dobeln age correction factors. These two predictions in $L.min^{-1}$ were then converted to $ml.kg^{-1}.min^{-1}$.

Maximal Test

Following a 5 minute rest, each subject performed a maximal test similar to that described by Teraslinna, Ismail et al (1966). With a pedalling speed of 60 rpm, the work load was 25 W for the first 2 minutes. The work load was increased by 25 W every minute thereafter until the subject was exhausted. Additional criteria for immediate termination of the test included overt ECG changes, marked dyspnoea, confusion, pallor, or pain in the chest, arms, or jaw.

Each subject's expired gas was collected in meteorological balloons, and analysed for oxygen and carbon dioxide using Beckman OM-14 and LB-2 analysers, respectively. Both analysers were calibrated with known gas mixtures. If the $\dot{V}O_2$ of the last two bags were within 0.25 $L.min^{-1}$, the test was considered valid.

RESULTS

The measured and predicted $\dot{V}O_2$ max are summarised in Table I. The data suggest that the $\dot{V}O_2$ max elicited by a maximal cycle ergometer test can be predicted from the Åstrand-Ryhming nomogram with a standard error of estimate of approximately .42 $L.min^{-1}$ or 5.6 $ml.kg^{-1}.min^{-1}$ (Table II), regardless of whether the Åstrand or the von Dobeln age correction factors are used. Although there was no statistically significant difference between the mean measured $\dot{V}O_2$ max and the mean prediction based on the Åstrand age correction factors, there was a significant difference when using the von Dobeln factors.

TABLE II

Correlation coefficients (*r*), standard errors of estimates (*SEE*), and *t*-tests between predicted and measured $\dot{V}O_2$ max

Method of Prediction	*r*	*SEE*	*t* (39)
Åstrand factors			
$L.min^{-1}$	.76	.42	−1.693
$ml.kg^{-1}.min^{-1}$	.83	5.7	−1.436
von Dobeln factors			
$L.min^{-1}$	.77	.41	−4.232*
$ml.kg^{-1}.min^{-1}$	.84	5.5	−3.783*

* $p < .05$, predicted vs. measured.

The reliability coefficient for the maximal test results was .95 (Table III). All reliability coefficients were computed from test-retest results completed within 96 hours.

During the submaximal test, the difference between the heart rates for the fifth and sixth minutes was greater than 5 bpm for 9 of the 40 subjects. Therefore, 23% of the subjects required submaximal tests of more than 6 minutes in order to achieve a submaximal steady state.

DISCUSSION

The mean measured $\dot{V}O_2$ max of 4.08 $L.min^{-1}$ or 54.6 $ml.kg^{-1}.min^{-1}$ is comparable to the data from a study of similar-aged subjects (P.-O. Åstrand and

TABLE I

Measured and predicted $\dot{V}O_2$ max

Method	X (SD)		Range	
	$L.min^{-1}$	$ml.kg^{-1}.min^{-1}$	$L.min^{-1}$	$ml.kg^{-1}.min^{-1}$
Measured	4.08 (.64)	54.6 (10.21)	3.03-5.38	40.3-79.8
Predicted using Åstrand factors	3.94 (.81)	52.9 (13.35)	2.4-5.3	34-88
Predicted using von Dobeln factors	3.75 (.77)	50.5 (12.65)	2.3-5.2	32-83

TABLE III

Reliability coefficients for measured and predicted $\dot{V}O_2$ max

Method		ra
Method		r^a
	$L.min^{-1}$	$ml.kg^{-1}.min^{-1}$
Measured[b]	.95	.95
Predicted using Åstrand factors[c]	.85	.87
Predicted using von Dobeln factors[c]	.80	.85

[a]Pearson product-moment correlation coefficient between test-retest results.

[b]$n = 7$. [c]$n = 15$.

Ryhming, 1954). These results indicate that roughly two-thirds of the $\dot{V}O_2$ max measurements elicited during a maximal cycle ergometer test will be within ± .42 $L.min^{-1}$ or ± 5.6 $ml.kg^{-1}.min^{-1}$ of the $\dot{V}O_2$ predicted from the Åstrand-Ryhming nomogram, with the stipulations that the submaximal test be conducted on a cycle ergometer and that the appropriate test procedures be followed.

Although there have been numerous other studies of the validity of predictions made from the Åstrand-Ryhming nomogram, comparison with these earlier results is frequently rendered somewhat difficult due to differences in testing modes or methods. For example, several studies have evaluated the nomogram using maximal treadmill tests either with submaximal treadmill tests (Rowell et al, 1964), or with submaximal cycle ergometer tests (Jessup et al, 1975; Glassford et al, 1965). Because the heart rate and $\dot{V}O_2$ responses to submaximal or maximal tests on the treadmill differ from the responses to tests with the cycle ergometer, using the treadmill would be expected to reduce the accuracy of the predicted $\dot{V}O_2$ max.

Of those studies that have used the cycle ergometer for both the maximal and submaximal tests, several have used submaximal tests lasting for a specified time of six minutes or less (von Dobeln, I. Åstrand et al, 1967; Teraslinna, Ismail et al, 1966). In the present study, 23% of the subjects had not met Åstrand's (a) criteria for establishing a submaximal steady state by the sixth minute of their submaximal tests.

Glassford et al (1965), using appropriate testing modes and procedures, reported correlation coefficients of .65 and .63 for predictions in $L.min^{-1}$ and $ml.kg^{-1}.min^{-1}$, respectively. These lower values may in part reflect the lower standard deviations of their measured $\dot{V}O_2$ max, which were only .402 $L.min^{-1}$ or 4.67 $ml.kg^{-1}.min^{-1}$. Bonen et al (1979) suggest that homogeneously distributed data will reduce the magnitude of correlation coefficients; these authors suggest that standard errors of estimate or coefficients of variation are better indicators of relative predictive accuracy.

The results of the present study also indicate that when the subjects are being classified into various fitness categories, (i.e., well-trained, moderately trained, or untrained), the Åstrand age correction factors should be used. The statistically significant difference between the mean measured $\dot{V}O_2$ max and the mean predicted value using the von Dobeln age correction factors indicates a consistent tendency to underestimate the actual $\dot{V}O_2$ max. The use of the von Dobeln age correction factors would therefore result in more subjects being assigned to lower categories than would be the case if the $\dot{V}O_2$ max were directly measured. The predictions based on the Åstrand age correction factors would not exhibit this tendency.

However, when predicting the $\dot{V}O_2$ max for a given subject, the Åstrand and the von Dobeln age correction factors can be used interchangeably because the standard errors of estimate of the resulting predictions are essentially identical.

Improvements in the current version of the Åstrand-Ryhming nomogram may be possible by eliminating the maximal treadmill test data and by avoiding the use of multiple submaximal tests by a given subject in a single day, which was done when the modified version was computed (I. Åstrand, 1960).

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BOOK REVIEW

Title:	**1980 YEAR BOOK OF SPORTS MEDICINE**			
Editors:	T. B. Quigley and Others			
Publisher:	Year Book Morby, Chicago and Year Book Publishers, London			
	Price: £28.50	80 Figs.	37 pages	Author Index and Subject Index

Compared with the 1979 Year Book, reviewed in this journal by John Williams, the 1980 version is some 80 pages longer, and the addition of John G. P. Williams, Ejnar Eriksson and H. Nakajima as corresponding editors, and Roy Shephard to the main editing team have made the current book much less parochial and U.S. orientated.

The book comprises two leading articles, one the Winter Olympic Games at Lake Placid, and on Olympic boxing, then abstracts of half to two pages length with comments on each by one or other of the editors. Topics include exercise physiology, biomechanics, general medicine, sports traumatology, womens' and childrens' special problems in sport, and athletic training.

Most of the criticisms of the first, 1979, edition have now been answered, and in the short time taken the editors have performed a big task in collecting, abstracting and commenting upon the work of some 325 authors. This second edition is expensive for the casual reader who may want to keep up to date with annual editions, but of great value to the library of a sports medicine centre, medical school, physical education college or school of physiotherapy.

H. E. Robson